The *Dauer Mutation* of the *Caenorhabditis Elegans*, simulated with the Penna and the Stauffer Model

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Abstract

Two ageing models were analysed whether they can confirm that the *dauer mutation* of the *nematode* helps to preserve the species. As a result the Penna model shows that populations with *dauer larvae* survive bad environmental conditions, whereas populations without it die out. In the Stauffer model the advantage of the *dauer mutation* for the survival is only given under certain conditions.

Keywords: Biological Ageing; Caenorhabditis Elegans; Dauer mutation; Monte Carlo simulation; Penna Model; Stauffer Model.

1 Introduction

Some animals like the small nematode *Caenorhabditis Elegans* have a mutation which is called *dauer*. Their study may help our understanding of ageing in general. Finch and Kirkwood discovered that ageing worms get randomly damaged cells, like humans, [1] and Herndon et al. claimed that old worms, like old people, suffer muscle decline [2].
At the existence of a pheromone (a measure of population density), high temperatures or a food shortage at the end of the second larvae stage, the *nematode* can go into a mutated third larvae stage being able to move but needing no food [3]. This stage can be passed through 6 to 8 times until the conditions have improved [3]. As the *after-dauer* life span is not influenced by the endurance of the larvae stage, scientists agree that the *nematodes* do not age during the *dauer state* [3]. This paper deals with the question if the *dauer mutation* helps a population to preserve its species in bad times. For the Dasgupta model, this was already answered positively by Heumann [4].

2 The *dauer mutation* simulated with the asexual Penna model

The 1995 developed asexual Penna model is a *bit-string model*, in which each genome of an individual is represented by a computer word of 32 bits. A bit set to zero represents a healthy gene, whereas a bit set to one symbolises a hereditary disease that becomes active in the "year" (or other suitable time unit) represented by the position of the bit. Exceeds the number of active diseases a certain threshold, the individual dies [5]. For further information about the asexual Penna model see e.g. [5] or [6].
The original Penna model is now modified so that it contains an environmental condition after reaching a stable population. In this environmental condition each

tenth summer is a bad one in which only 1% of the population survive. After this bad tenth summer, as an option in the program, up to three more bad summers can follow one after the other, each with a probability of 0.5. Furthermore the *dauer mutation* is included in the computer program so that all *nematodes* of age 3 (representing the individuals in the third larvae stage) do not die in these bad summers. The other parameters were chosen as in the program listed in [5], if not stated otherwise. A summer means approximately one day in the *Caenorhabditis Elegans'* life, as its mean life span is about 20 days [7]. In addition the *dauer larvae* do not age in this simulation.

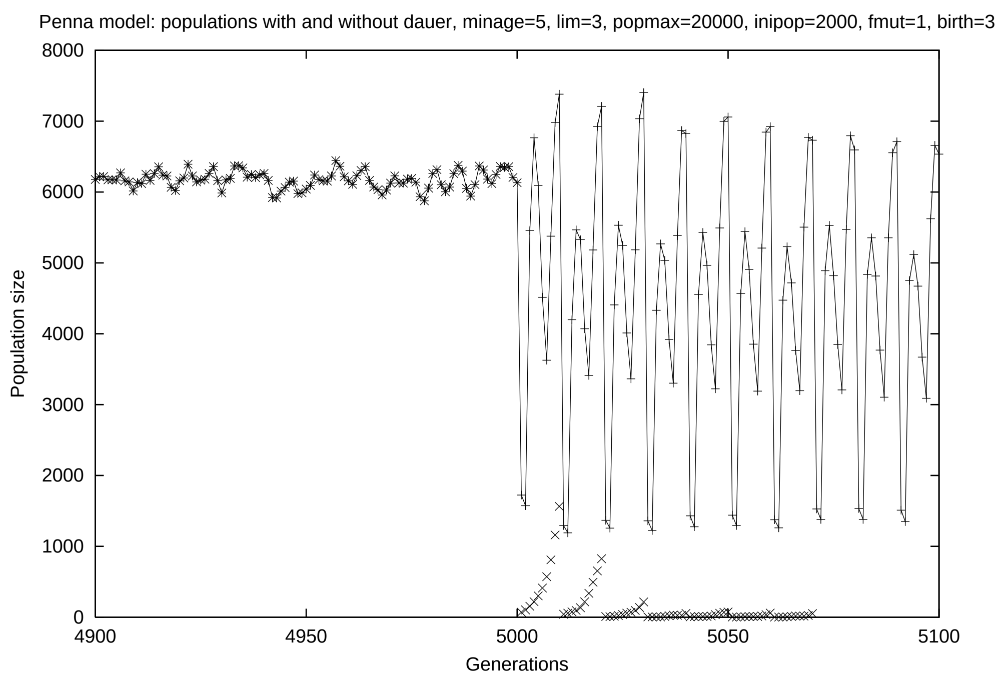

Figure 1: After 5000 generations, in each tenth summer only 1 % survive. '+'=population with dauer, 'x'=population without dauer

As a result figure 1 shows the comparison between a population with *dauer* and one without it. The population size is plotted versus the generations.
The population with the *dauer mutation* survives the bad conditions showing extreme fluctuations, whereas the population without the *dauer larvae* dies out in the seventh bad summer.
Figure 2 shows the comparison between a population with and one without *dauer larvae* at extreme conditions with up to four bad summers one after the other. This close-up shows the time between 4980 and 5020 generations. Again the population with *dauer* survives, the population without it is already extinct in the second bad summer.

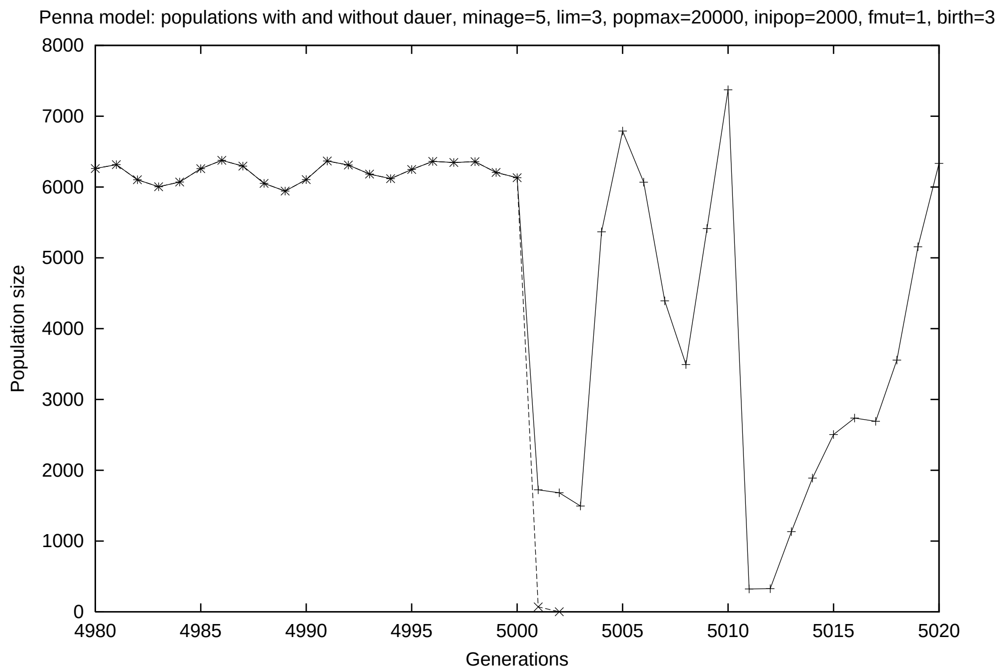

Figure 2: After 5000 generations, each bad tenth summer may be followed by up to three bad ones. '+'=population with dauer, 'x'=population without dauer

3 The *dauer mutation* simulated with the Stauffer model

Stauffer suggests a simple alternative to the Penna model ([8],[9]) that does not consider an explicit bit-string as genome. In this Stauffer model only the minimal reproduction age $a_m(i)$ and the genetic death age $a_d(i)$ are transmitted from generation to generation [10]. Having achieved the minimal reproduction age, the individual produces offspring with the probability b

$$b = \frac{1+\epsilon}{a_d(i) - a_m(i) + \epsilon}$$

with the parameter $\epsilon = 0.08$ to avoid divergences and extinction of the population [9]. Thus the birth rate is the smaller the longer the reproduction phase of the parent is: *fecundity-survival trade-off* [8]. The offspring inherits $a_m(i)$ and $a_d(i)$ from the parent with a mutation of ± 1 "year" [8].
The individuals reach at most their genetic death age [9]. They can die with a *Verhulst probability* representing food and space restrictions as in the Penna model. The *Verhulst survival probability* is given by $V = 1 - N/N_{max}$ with N_{max} the capacity of the ecosystem [8].
Programming this model showed that a small difference in the interpretation leads to relevant effects on the results obtained. Whereas in Stauffers program the individual can get its first child with the age $> a_m$, in my program the reproduction starts already with reaching a_m. This difference results in a population that is about twice as high as in Stauffers version. The mortality in both versions consequently shows differences indicating a slightly better exponential increase in Stauffers in-

terpretation. However both versions are regarded showing also differences in the simulation of the *dauer larvae*.

In analogy to our simulation with the Penna model an environmental condition and the *dauer state* are included. The parameter s_b indicates how much of the population survives in the bad summer because of the environmental condition. In the case of the modified Penna model a disastrous summer was simulated: $s_b = 0.01$.

Figure 3 shows populations with and without *dauer mutation* for disastrous summers with $s_b = 0.01$ and summers with $s_b = 0.61$. It can be seen that all populations die out in Stauffers version, whether they have *dauer larvae* or not, even when the summer with $s_b = 0.61$ is not catastrophic. The *dauer state* helps here very little.

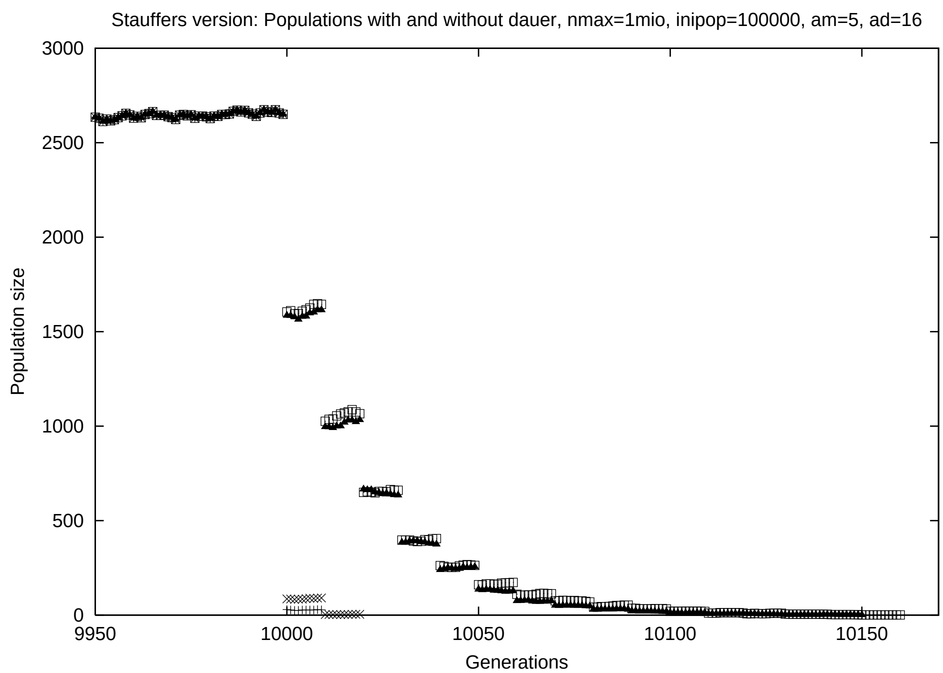

Figure 3: After 10000 generations, each tenth summer is a bad one. 'x'=population with dauer,$s_b = 0.01$, '+'=population without dauer, $s_b = 0.01$,'square'=population with dauer, $s_b = 0.61$, 'triangle'=population without dauer, $s_b = 0.61$

Figures 4, 5 and 6 show my version with the same parameters as in figure 3. In my version both populations also die out for $s_b = 0.01$, shown in figure 4. Figure 5 illustrates a population without *dauer* dying out after a few bad summers at $s_b = 0.61$, whereas the population with the *dauer state* in figure 6 survives those conditions.

The comparison of the two versions shows that a small difference in the interpretation of the model can lead to totally different results concerning the preservation of the species.

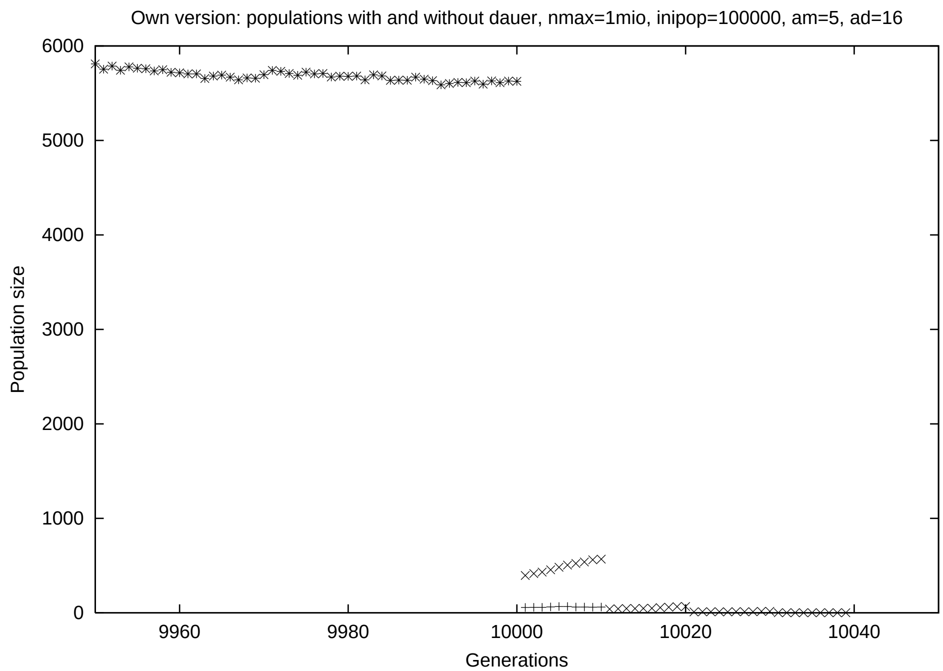

Figure 4: After 10000 generations, in each tenth summer only 1 % survive. 'x'=population with dauer, $s_b = 0.01$, '+'=population without dauer, $s_b = 0.01$

Figure 5: After 10000 generations, in each tenth summer 61 % survive.

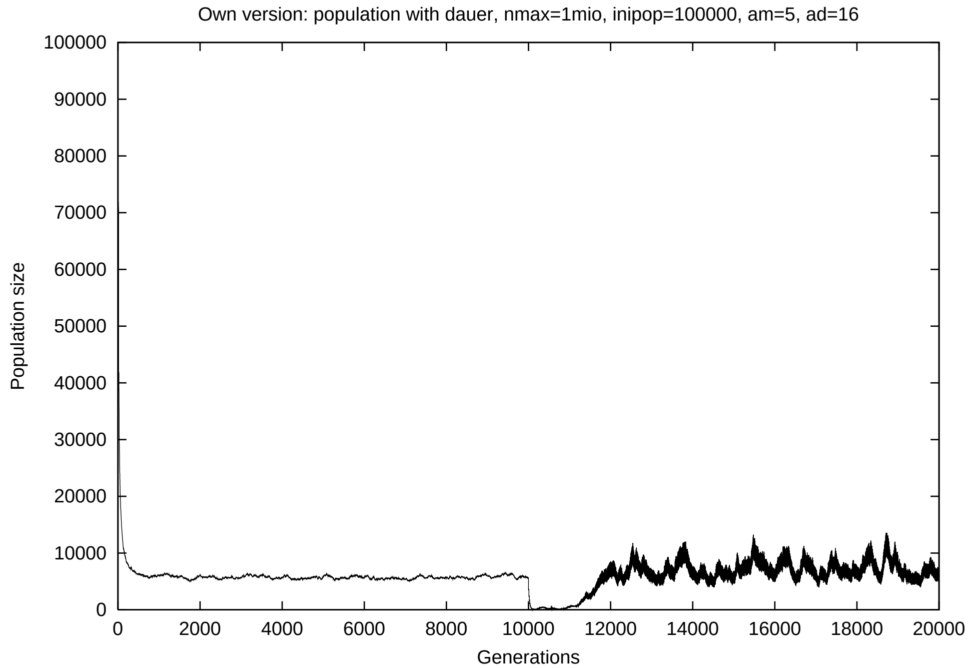

Figure 6: After 10000 generations, in each tenth summer 61 % survive.

3.1 The Stauffer model with increased birth rate

This difference in the two versions introduces the question which parameters lead to a preservation of the *dauer population* in Stauffers interpretation. As increasing the *bad summer factor* s_b up to $s_b = 0.9$ still kills the population with *dauer mutation*, a change in the birth rate might show the advantage of the *dauer larvae* for the preservation of the species. Iterating the birth loop twice in Stauffers version, provides the results in figure 7 for $s_b = 0.23$. Whereas the population with *dauer mutation* survives the bad conditions, the population without it dies out (the small dots ending near generation 10000).

Analysis showed that for $s_b = 0.23$ and higher the population with *dauer larvae* survives, whereas the population without it dies out. Is $s_b < 0.23$ both populations are extincted. Thus an increased birth rate in Stauffers version leads to the preservation of the species for $s_b = 0.23$ and higher.

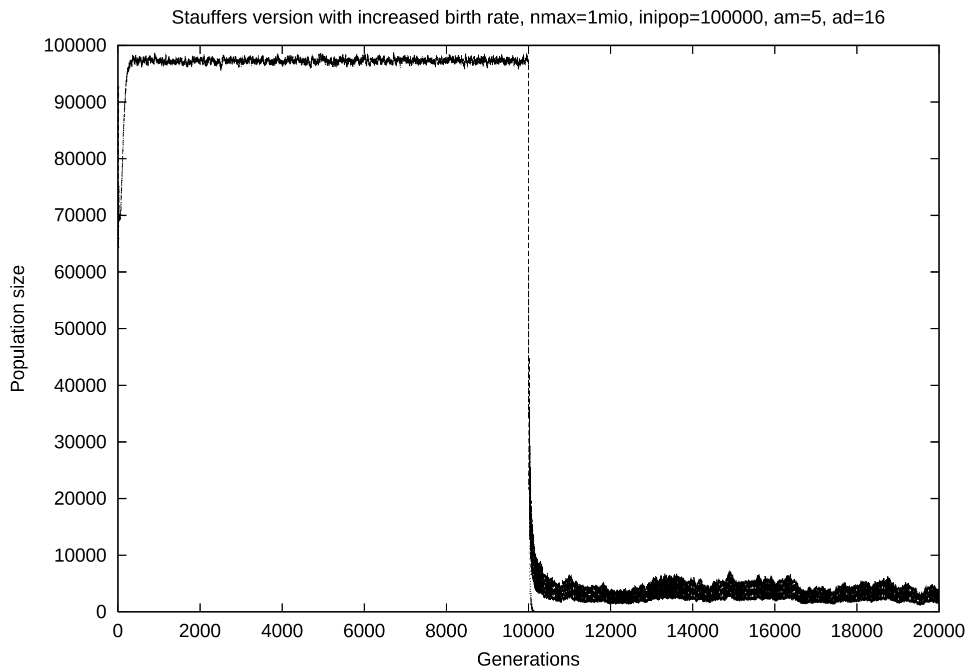

Figure 7: After 10000 generations, in each tenth summer 23 % survive. 'lines'=population with dauer, $s_b = 0.23$, 'dots'=population without dauer, $s_b = 0.23$

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